REMARKS

Amendments:

Claims 1, 9, 31, 32, and 33 have been amended. New claims 34-41 have been added. No new matter is added by the amendments to the claims, and the new claims are fully supported by the application as-filed. Claim amendments and the new claims find support throughout the Specification and at paragraphs 34, 39, 41, 43, 45, and 52 of the Specification as-filed.

The Applicants respectfully request reconsideration of the claims.

The Invention As-Claimed:

As recited in amended claim 1, the invention provides a carbon nanotube device. The device has a substrate including an aperture extending from a front surface to a back surface of the substrate. At least one pair of electrically conducting contact pads is disposed on a selected one of the front and back substrate surfaces. The conducting contact pads in a given pair of pads are separated from each other by the aperture in the substrate surface on which they are together disposed.

A carbon nanotube catalyst region is disposed on top of each of the contact pads on the selected substrate surface, in alignment with an edge of the aperture. The catalyst regions are exposed at the selected substrate surface. At least one carbon nanotube extends across the aperture and is accessible through the aperture from both the front surface and the back surface of the substrate. Each end of the carbon nanotube contacts an exposed catalyst region on a contact pad at the selected substrate surface.

Claim Rejections:

Claims 1-6, 8-11, 15, and 31-33 were rejected under 35 U.S.C. §103(a) as being unpatentable over Brown et al., U.S. No. 6,297,063 (hereinafter "Brown") in view of Hunt et al., U.S. patent application publication US 2002/0167374 (hereinafter "Hunt").

The Examiner suggested that Brown teaches a carbon nanotube device having a substrate 10 (Brown reference numeral). The Brown structure was said to have at least one pair of electrically conducting contact pads disposed on a selected one of front and back substrate surfaces and separated by an aperture; the Examiner here referred to element 12a (which is referred to in Brown Fig. 1A) and Brown Fig. 5B.

Below are reproduced Brown Fig. 1A and Brown Fig. 5B for ease of reference.

FIG. 1A

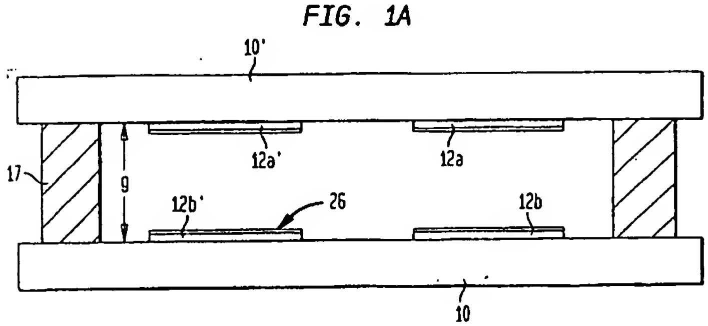
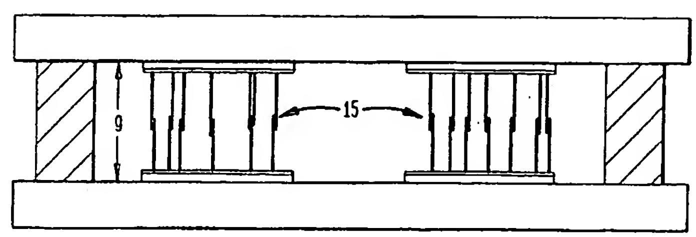


FIG. 5B



In Brown Fig. 1A there are shown "two mating circuit substrates 10, 10', having electrical contact pads thereon 12a, 12b, 12a', 12b'," (Brown Col. 4, lines 12-14). In Brown Fig. 5B there are shown "nanowires...grown separately on two mating circuit substrates 10, 10'...[with] bonding 15 occurring between adjacent nanowires," across the gap g (Brown Col. 6, lines 48-49, 55, and 58-59).

The invention as recited in claim 1 requires a substrate having an aperture extending from a front surface to a back surface of the substrate. Brown does not teach or hint at such a configuration, and is silent on this point as agreed upon by the Examiner. The Brown substrates 10, 10' are each solid and include no apertures.

The claims further require, as recited in claim 1, at least one pair of electrically conducting contact pads disposed on a selected one of the front and back surfaces of the substrate that includes the aperture. Brown does not teach or suggest a substrate with an aperture and accordingly does not teach or suggest contact pads in a pair of pads that are both on a substrate having an aperture. Brown's contact pads 12, 12a', 12b, 12b' are provided on substrates 10, 10' that are solid.

The claims further require that that the contact pads in a given pair of pads be separated from each other by the aperture in the substrate on which the contact pads of the pair are together disposed. The Applicants respectfully presume that the Examiner construed the gap g between two mating substrates 10, 10' in the Brown structure as an aperture. But such does not meet the requirement of the claims that contact pads in a given pair be separated from each other by an aperture <u>in the substrate on the surface of which both contact pads in the pair are disposed</u>.

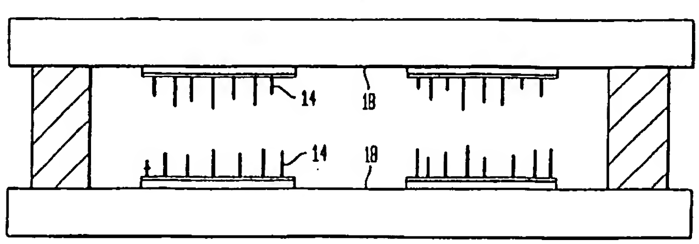
The contact pads 12a, 12a' of the Brown substrate 10' form a pair of contact pads disposed on a selected surface of the substrate 10', but there is no aperture in the substrate 10' separating the contact pad pair 12a, 12a' as required by the claims. Similarly, the contact pads 12b, 12b' of the Brown substrate 10 form a pair of contact pads disposed on a selected surface of the substrate 10, but there is no aperture in the substrate 10 separating the contact pad pair 12b, 12b' as required by the claims. The claims require that the aperture be in the substrate on which the pair of contact pads is disposed so that the aperture separates the pads in the pair from each other.

The Examiner suggested that Brown teaches a carbon nanotube catalyst region 26 on top of each of the contact pads and exposed at the selected substrate surface. The Applicants concur that Brown teaches "a catalytic nucleation layer 26...disposed on the surface of each contact pad," (Brown Col. 4, lines 24-25).

The Examiner suggested that Brown teaches at least one carbon nanotube extending across the aperture; the Examiner referred to Brown element 14, referred to Brown Col. 1, lines 26-52, and to Brown Fig. 6C. Brown Col. 1, lines 26-52 are in the Brown Background section and describe generally the characteristics of carbon nanotubes. There is no reference to a particular nanotube configuration or aperture in a substrate in that passage. The Applicants note that Brown Col. 4, lines 64-67 describe "nanowires" as being "nucleated and grown toward each other. Fig. 1B, for example, shows two nanowires 14, 14 growing toward each other."

Brown Fig. 1B is reproduced below for ease of reference. In Brown Fig. 1B there are shown the two nanowires 14, 14 growing between two surfaces 18, 18. The nanowires are growing between the two substrates identified as 10, 10' in Fig, 1A above. But the claims require that a nanotube extend across an aperture in a substrate on a surface of which are disposed contact pads that are separated by the aperture. The aperture, contact pads, and nanotube are all in arrangement with a single substrate. There are no apertures in the Brown substrates 10, 10', and the nanowires 14, 14 grow between substrates, not across an aperture in a selected one of the substrates as required by the claims.

FIG. 1B



The Examiner suggested that Brown teaches a nanotube each end of which is located on top of an exposed catalyst region at the selected substrate surface, and referred to Brown Fig. 5B. In Brown Fig. 5B nanowires that are bonded 15 between two substrates are shown. The claims require that each end of a nanotube contact an exposed catalyst region on a contact pad at the selected substrate surface. In other words, the contact pads and catalyst regions are on a common selected surface having an aperture therein and each end of the nanotube contacts one of the catalyst regions on the surface, across the aperture. Brown does not teach or suggest this configuration.

Instead, each Brown bonding of two nanowires extends the nanowires between two different substrates, namely the upper substrate 10' and the lower substrate 10. Brown neither teaches nor suggests an arrangement in which a nanotube extends across an aperture in one single substrate on a surface of which is provided a pair of contact pads separated by the aperture in the substrate as required by the claims. Brown therefore fails to teach or suggest the carbon nanotube device required by the claims.

As explained previously, the invention provides particular advantages with the requirement, as recited in amended claim 1, of a substrate through which an aperture completely extends between two surfaces for separating contact pads on one of the surfaces. As explained at ¶¶26-27 of the instant Specification, with a substrate including such an aperture, a nanotube can be synthesized to form a bridge across the aperture to make contact between two electrodes that are provided on a surface of the substrate. As explained at ¶28, gas or liquid can then be directed through the substrate itself for nanotube-based sensing or other applications. This enables a compact arrangement in which nanotube synthesis is incorporated with planar microfabrication to produce planar, substrate-based nanotube devices and systems, and allows for use of a microfabrication substrate directly in a nano-electromechanical application.

Brown teaches configurations for connecting a nanowire between two substrates, not for extending a nanotube across an aperture on a substrate on a surface of which is provided a pair of contact pads separated from each other by the aperture as required by the claims. Brown provides no teaching or even hint at the formation of an aperture through the full thickness a substrate and a carbon nanotube bridge across the aperture and connected between catalyst regions on two contact pads on a selected substrate surface as required by the claims.

The Examiner referred to Brown Fig. 6C as showing horizontal nanotube. Brown Figs. 6A-6C depict nanotube synthesis between horizontal circuit interconnections (Col. 7, lines 4-6). In this scenario, Brown teaches the formation of a nucleation layer 26 and blanket-coating of the nucleation layer with an insulating layer 102. "A horizontal slot" is then cut through the layer structure and nanowires are grown horizontally across the slot above a substrate 100 (Col. 7, lines 25-43).

The carbon nanotube device of the invention as recited in amended claim 1 requires at least one pair of contact pads separated by an aperture between two surfaces of a substrate, with a catalyst region on top of each pad and exposed at the substrate surface. In great contrast, in the Brown horizontal synthesis, the catalyst layer is <u>not</u> exposed at the substrate surface. As shown clearly in Brown Figs. 6A-6C, the catalyst layer is covered by a blanket coat of an insulating layer.

In Brown's arrangement, a nanotube 114 is to be synthesized from a side face of a catalyst layer which is exposed by the cutting of a slot 104. The upper insulating layer is employed in an effort to inhibit vertical growth of nanotubes and in an effort to encourage horizontal growth. The use of such a vertical growth preventing layer was at one time conventionally understood to be required.

But it has been discovered in accordance with the invention that the likelihood of success of Brown's arrangement in a nanotube growing across a slot from a first catalyst side face to a second catalyst side face is very low. As nanotubes grow, they tend to flop around and then stick to a surface they eventually fall to and contact through Van der Waals forces. The Brown arrangement does not accommodate this behavior and requires that a nanotube "find" an end face of a catalyst layer .

The invention provides a discovery that carbon nanotubes can be synthesized horizontally without requiring the blanket vertical growth preventing layer employed by Brown. In the invention, each catalyst region is disposed fully exposed at a substrate surface. For example, as shown in Fig. 7C and Fig. 9 of the instant Specification, a catalyst region 26 atop each of two contact pads 16 is fully exposed, i.e., is not covered by other material layers. Then as shown in Fig. 7D of the instant application, a carbon nanotube 10 is synthesized between two of the exposed catalyst regions. Brown neither teaches nor suggests that a catalyst layer could be exposed at a substrate surface and instead requires that the catalyst layer be coated with a growth preventing layer.

In contrast, the exposure of catalyst regions in accordance with the invention as recited in claim 1 enable nanotubes to directly access planar catalyst region surfaces as the tubes are synthesized, and thus enable successful horizontal nanotube growth. This arrangement and the fabrication process of the invention overcome the severe limitations of the Brown arrangement with a discovery that a vertical growth-suppression layer is not only unnecessary but deleterious to successful nanotube growth. In that respect, Brown actually teaches away from the arrangement of the invention.

Thus both Brown nanotube arrangements fail to meet the requirements of the claims: neither Brown's nanowire connection between two substrates nor Brown's slotted horizontal nanotube synthesis provide the requirements of the claims. Brown never

teaches or suggests how one might make an aperture through a substrate and provide a nanotube across the aperture, between two contact pads, with ends of the nanotube located on top of exposed catalyst regions on the substrate surface. In Brown's first scenario, Brown is concerned solely with making electrical connections between two different substrates, and there is no teaching or suggestion for forming an aperture in a substrate for nanotube synthesis across the aperture in that substrate. In Brown's second scenario, Brown is concerned with synthesizing horizontal nanotubes by employing a blanket coating over a catalyst layer and requiring nanotubes to grow from end faces of the catalyst layer. There is no teaching or suggesting by Brown for forming an aperture through the substrate, and there is not even a hint that horizontal nanotube synthesis could be carried out with catalyst regions exposed on the substrate surface rather than blanket-coated by an upper layer.

The Examiner indicated her agreement with the Applicants that Brown is silent as to a substrate having an aperture extending from a front surface to a back surface with a carbon nanotube accessible through the aperture from both the front surface and the back surface. The Examiner suggested that Hunt teaches a carbon nanotube device, shown in Hunt Fig. 11, wherein a substrate comprises an aperture extending from a front surface to a back surface of the substrate with at least one carbon nanotube extending across the aperture and accessible through the aperture from both the front and back surfaces of the substrate. The Examiner referred to Hunt ¶71 for a description of the Hunt device of Fig. 11.

The Applicants respectfully submit that Hunt Fig. 11 is a schematic representation of a variance of the device of Hunt Fig. 1, only being "shown schematically" (¶71). Based on the correspondence of Hunt Fig. 1 with Hunt Fig. 11, it is unequivocally clear that Hunt intends Fig. 11 to include all of the features of Hunt Fig. 1, including a solid substrate with no aperture as suggested by the Examiner. Hunt makes this certain in that in Hunt Fig. 11 there are labeled elements 14, 16, which are not described in ¶71, but which are described with reference to Hunt Fig. 1: regions 14 and 16

are first and second "supports" on a substrate 12 in Fig. 1 (¶41, first sentence). Hunt uses the reference numerals 14, 16 to refer to substrate supports throughout the Hunt Specification and it is clear that supports on a substrate are to be conveyed in Hunt Fig. 11.

It is understandable that Hunt omitted an explicit representation of a substrate in Hunt Fig. 11 because Hunt omitted many of the features of Hunt Fig. 1 from Hunt Fig. 11 to emphasize the inclusion of "multiple resonators aligned on a single substrate." (¶71, first sentence). For example, the catalyst region 17, electrodes 18, 20, and RF input 28 of Hunt Fig. 1 are omitted from Hunt Fig. 11. But such are clearly intended as included in the structure of Hunt Fig. 11. By calling the nanotubes of Hunt Fig. 11 "resonators" and describing their integration into an RF spectrum analyzer in ¶71, it is clear that an RF input is intended and required in the structure of Hunt Fig. 11, and the RF input 28 of Hunt Fig. 1 is thereby intended to be supplied on a substrate in Hunt Fig. 11. Further by characterizing the nanotubes of Hunt Fig. 11 as "aligned on a single substrate" in ¶71 it is clear that the substrate 12 of Hunt Fig. 1, required to support the RF input 28 and the supports 14, 16, is the substrate on which the nanotubes are to be aligned.

Thus, there can be no conclusion other than that the Hunt Fig. 11 device is a schematic representation of the Hunt Fig. 1 device with an additional nanotube structure and that a substrate must exist under the substrate supports 14, 16 in the Fig. 11 device. The Hunt Fig. 11 device would not operate in accordance with the description of Hunt ¶71 otherwise. In fact, the Hunt Fig. 11 device would be entirely inoperable if a substrate were not included because the RF input 28 for the device could not be provided under the nanotubes. Every aspect of the description of Hunt ¶71 and the correspondence between Hunt Fig. 1 and Hunt Fig. 11 indicate that Hunt intended the reader to understand that the features of the Fig. 1 device are included in the Fig. 11 device. The Hunt Fig. 1 and Fig. 11 devices therefore both include solid, continuous substrates on which are provided supports 14, 16. Hunt therefore adds nothing to the Brown structure and fails to provide the claim elements missing from the teaching of Brown.

Even if, for the sake of argument only, Hunt is presumed to teach a substrate having an aperture, there is no motivation to combine the RF nanoresonator device of Hunt with the vertical nanowire substrate interconnections of Brown. MPEP 2143 requires that "there must be some suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine reference teachings." "The teaching or suggestion to make the claimed combination...must be found in the prior art, not in applicant's disclosure, *In re Vaeck*, 947 F.2d 488, 20 USPQ2d 1438 (Fed. Cir. 1991)."

Brown is concerned solely with making a connection between two substrates by way of nanowires. Hunt is concerned solely with resonating nanotubes for a resonator device. There is absolutely nothing in the substrate interconnection technique of Brown that would benefit from an aperture in either of the substrates being connected by a nanowire. Brown simply is focused solely on making a nanowire connection between two substrates, and does not describe or suggest any particular features of the two substrates. Hunt is concerned solely with a structure that enables a nanotube to resonate, and does not teach or suggest any technique or even motivation for making an interconnection between two substrates. Brown and Hunt do not provide any hint of motivation to include any of the features of the other, and no motivation can be found in the general skill of the art; there simply would be no benefit from the combination.

The Applicants therefore respectfully submit that neither Brown no Hunt, nor any proper combination of the two, teach or suggest the claimed invention.

Claims 2-15 and 31-41 depend from claim 1 and include all of the limitations of claim 1. Thus, for any combination of recited limitations in the dependent claims that are suggested by Brown and/or Hunt, Brown and Hunt fail to teach or suggest the limitations of claim 1 as included in all other claims.

For example, claim 2 requires a single-walled carbon nanotube; claim 3 requires a multi-walled carbon nanotube; claim 4 requires a semiconducting carbon nanotube; claim 5 requires a metallic carbon nanotube; and claim 6 requires a plurality of carbon nanotubes. Claim 15 requires a plurality of pairs of contact pads. For any specific carbon nanotube characteristic, number of nanotubes, or number or contact pads suggested by Brown, Brown and Hunt fail to teach or suggest a substrate having an aperture through the substrate and a carbon nanotube extending across the aperture and connected between catalyst regions that are exposed on the substrate and on top of contact pads on the substrate as required by the claims.

Claim 8 requires that the substrate be a semiconducting substrate. For any substrate employed by Brown, Brown requires either the use of two such substrates, between which nanotubes are vertically synthesized, or Brown requires the use of a slotted substrate having a blanket layer covering a catalyst layer as explained above, both as described above. Hunt requires a solid substrate on which are provided substrate supports, as explained above. In contrast, the claims require the use of one substrate through which is provided an aperture and on which are provided catalyst regions that are exposed on a substrate surface. Brown and Hunt fail to teach or suggest such.

Claim 9 requires that the substrate include a membrane; claim 10 requires that the membrane be a silicon nitride membrane; and claim 11 requires that the membrane be a silicon dioxide membrane.

The Examiner here pointed to the Brown description at Col. 4, lines 24-37, suggesting that Brown reference numeral 26 refers to a membrane. The Applicants respectfully submit that this is not the case. Brown reference number 26 refers to a catalyst layer, i.e., a "catalytic nucleation layer 26," (Col. 4, line 24). Brown explains that the catalyst layer 26 is "disposed on the surface of each contact pad," (Col. 4, lines 24-25).

The Brown catalyst layer is identified in Fig. 1A where the reference numeral 26 and associated reference line point to a layer on top of a contact pad 12b' that is on a substrate 10. The Brown catalyst layer is not a membrane – it is simply a layer provided on top of a contact pad on a substrate.

Fig. 7C-7D of the instant application illustrate example membranes in accordance with the invention. There is provide a membrane material 18 on top of a substrate 12. An aperture 14 is formed through the membrane, with a nanotube 10 synthesized between catalyst regions 26 on top of contact pads 16 provided on the membrane structure. A membrane is a well-known micromechanical structure that is a suspended layer akin to a trampoline – there is no structure underlying the center of the membrane such that the membrane is free to deflect. Brown neither teaches nor in any way suggests a membrane in which is provided an aperture and across which a nanotube is provided. It appears that the Examiner has mistaken the Brown catalyst layer for a membrane.

Amended claim 12 requires that the substrate be aligned between a source of electrons and an electron detector for nanometer-scale transmission electron microscopy of the carbon nanotube.

Claim 12 was rejected under 35 U.S.C. §103(a) as being obvious over Brown in view of Hunt and further in view of Bradley et al., U.S. Publication No. 20040043527 (hereinafter "Bradley"). Referring to Bradley ¶¶55-56, the Examiner suggested that Bradley teaches a support structure holding a nanotube and aligned with a source of electrons and an electron detector for transmission electron microscopy.

The Applicants respectfully submit that this is not the case. In Bradley Fig. 2, referred to at ¶¶55-56, there is shown a substrate 230. A nanotube 210 is shown laying on the surface of the substrate 230. A voltage supply 240 applies a voltage to the substrate

230. A second supply 250 provides the same voltage to the nanotube. A meter 260 measures the difference in current through the nanotube that results from exposure of the nanotube to an environment of interest. (¶¶55-56).

This electrical circuit and current measuring technique is not transmission electron microscopy as required by claim 12. Microscopy, by definition, involves forming a micro-scale image. In transmission electron microscopy (TEM), electrons are directed through a structure of interest and after passing through the structure, are collected at a detector. TEM is not an electrical circuit such as that shown by Bradley.

As explained in the instant specification at ¶27, it is generally recognized by those skilled in the art that nm-scale TEM resolution is required to enable sufficient precision in nanotube analysis. Such cannot be achieved if the transmitting electrons must traverse a substrate. It is discovered in accordance with the invention that the substrate aperture provided by the invention enables alignment of the substrate between a source of electrons and an electron detector so that TEM can be carried out on a nanotube in place across an aperture in a substrate without the need to remove the nanotube from the substrate. No destruction of a nanotube under investigation is required to achieve nanometer-scale TEM resolution.

Neither Bradley, nor Brown or Hunt, nor any combination of the three, teach or even hint at transmission electron microscopy, let alone nanometer-scale transmission electron microscopy and how such could be carried out with a nanotube in place across an aperture on a substrate as required by the claim.

With this discussion the Applicants respectfully submit that the claims are in condition for allowance, which action is requested. If the Examiner has any questions or would like to discuss the amendments, she is encouraged to telephone the undersigned Agent at the number given below.

Fees for New Claims:

For	No. Filed		No. Paid		No. Extra	Sm/Lg Rate	FEE
Total Claims:	41	-	33	=	8	$25/$50	$400.00

NEW CLAIM FEE: **$400.00**

Enclosed is a check in the amount of $400.00 to cover the new claim fee. If there are any other additionally required fees beyond those indicated above, or any credits, please apply such to Deposit Account No. 12-1760.

Respectfully Submitted

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